The Nervous System

Before You Read
When you make a telephone call, telephone wires transmit messages electronically from location to location. In the same way, electrical impulses travel through the human body, allowing some parts to communicate with others. On the lines below, list three examples of types of messages you think may be transmitted within your body.

Read to Learn

Neurons: Basic Units of the Nervous System

The basic unit of structure and function in the nervous system is called the neuron, or nerve cell. Neurons (NYU rons) conduct impulses throughout the nervous system. As shown below, a neuron is a long cell that consists of three regions: a cell body, dendrites, and an axon.

Dendrites (DEN drites) are branchlike extensions of the neuron that receive impulses and convey them toward the cell body. The axon is an extension of the neuron. It carries impulses away from the cell body and toward other neurons, muscles, or glands.

Neurons fall into three categories: sensory neurons, motor neurons, and interneurons. Sensory neurons carry impulses from the body to the spinal cord and brain. Interneurons are found within the brain and spinal cord. They process incoming impulses and pass response impulses on to motor neurons. Motor neurons carry the response impulses away from the brain and spinal cord to a muscle or gland.

How are impulses relayed?
Imagine that you are in a crowded, noisy store and you feel a tap on your shoulder. You turn your head, and you see a friend standing behind you. What happened in your body to cause the tap to get your attention? First, the touch stimulated sensory receptors located in the skin of your shoulder. This produced a sensory impulse which was carried to the spinal cord and then to your brain. From the brain, an impulse was sent to your motor neurons, which transmitted the impulse to the muscles in your neck. The result? Your neck muscles turned your head in response to the tap.

What occurs when the neuron is at rest?
You have learned that the plasma membrane controls the concentration of ions in a cell. Because the plasma membrane of a neuron is more permeable to potassium ions (K⁺) than sodium ions (Na⁺), more potassium ions are inside the cell membrane than outside it. Similarly, more sodium ions are outside the cell membrane than inside it.

The neuron membrane also contains an active transport system, called the sodium/potassium (Na⁺/K⁺) pump. The pump uses ATP to pump sodium ions out of the cell and potassium ions into the cell. This increases the concentration of positive charges on the outside of the membrane. In addition, the presence of many negatively charged proteins and organic phosphates means that the inside of the membrane is more negatively charged than the outside.

Under these conditions, which exist when the cell is at rest, the plasma membrane is said to be polarized. A polarized membrane has the potential to transmit an impulse.

How are impulses transmitted?
When a stimulus excites a neuron, gated sodium channels in the membrane open up, allowing sodium ions to enter the cell. As the positive sodium ions build up inside the membrane, the inside of the cell becomes more positively charged than the outside. This is called depolarization. The change in the charge moves down the length of the axon like a wave. As the diagram on page 444 shows, the gated channels and the Na⁺/K⁺ pump then return the neuron to its resting state.

An impulse can only move down the complete length of an axon when stimulation of the neuron is strong enough. If the threshold level—the level at which depolarization occurs—is not reached, the impulse will die out quickly.

What are white and gray matter?
Most axons are surrounded by a white covering of cells called the myelin sheath. The myelin sheath is like the plastic coating on an electric wire. It insulates the axon, hindering the movement...
The Central Nervous System

When you make a telephone call to a friend, your call travels through wires to a control center. There it is switched over to wires that connect with a friend’s telephone. In the same way, an impulse travels through the neurons in your body. The impulse usually reaches the control center of the nervous system—your brain—before being rerouted. The brain and the spinal cord together make up the central nervous system, which coordinates all your body’s activities.

Another division of your nervous system is called the peripheral (puh-RILF) nervous system. It is made up of all the nerves that carry messages to and from the central nervous system. It is similar to the telephone wires that run between a phone system’s control center and the phones in individual homes. Together, the central nervous system (CNS) and the peripheral nervous system (PNS) respond to stimuli from the external environment.

How does the brain work?

The brain is the control center for the entire nervous system. It can be divided into three main sections. They are the cerebrum, the cerebellum, and the brain stem.

The cerebrum (SHUH REE-brum) is divided into two halves that are connected by bundles of nerves. The sections are called hemispheres. The cerebrum controls all conscious activities, intelligence, memory, language, skeletal muscle movements, and senses.

The outer surface of the cerebrum, called the cerebral cortex, is made up of gray matter. The cerebral cortex contains numerous folds and grooves that increase its total surface area. This increase in surface area played an important role in the evolution of human intelligence. Greater surface area allowed more and more complex thought processes.

The cerebellum (SEER-uhl-BELL-um) is located at the back of the brain. It controls balance, posture, and coordination. If the cerebellum is injured, movements can become jerky.

The brain stem is made up of the medulla oblongata, the pons, and the midbrain. The medulla oblongata (MED-ulla OBLONG-uh-tuh) is the part of the brain that controls involuntary activities such as breathing and heart rate. The pons and midbrain act as pathways connecting various parts of the brain to each other.

The Peripheral Nervous System

Remember that the PNS carries impulses between the body and the CNS. For example, when a stimulus is picked up by receptors in your skin, it initiates an impulse in the sensory neurons. The impulse is carried to the CNS. There, the impulse transfers to the motor neurons, which carry the impulse to a muscle.

The PNS can be separated into two divisions—the somatic nervous system and the autonomic nervous system.

What is the somatic nervous system?

The somatic nervous system is made up of 12 pairs of cranial nerves from the brain, 31 pairs of spinal nerves from the spinal cord, and all of their branches. These nerves are actually bundles of neuron axons bound together by connective tissue. The cell bodies of the neurons are found in clusters along the spinal column. Most nerves contain both sensory and motor axons.

The nerves of the somatic system relay information mainly between your skin, the CNS, and skeletal muscles. This pathway...
functions during times of stress. When something scares you, the sympathetic nervous system causes the release of hormones, such as epinephrine and norepinephrine, which results in a fight-or-flight response. The parasympathetic nervous system controls many of the body's internal functions when it is at rest. It is in control when you are reading quietly in your room. Both the sympathetic and parasympathetic systems send signals to the same internal organs. The resulting activity of the organ depends on the intensities of the opposing signals.

**After You Read**

**Mini Glossary**

- **autonomic nervous system (ANS):** in humans, portion of the peripheral nervous system that carries impulses from the central nervous system to internal organs; produces involuntary responses
- **axon:** extension of a neuron; carries impulses away from a nerve cell
- **central nervous system (CNS):** in humans, the central control center of the nervous system made up of the brain and spinal cord
- **cerebellum (ser uh BE lum):** rear portion of the brain; controls balance, posture, and coordination
- **cerebrum (suhr REE brum):** largest part of the brain, composed of two hemispheres connected by bundles of nerves; controls conscious activities, intelligence, memory, language, skeletal muscle movements, and the senses
- **dendrite (DEN drite):** branchlike extension of a neuron, transports impulses toward the cell body
- **medulla oblongata (muh DUH ol Bonnie):** part of the brain stem that controls involuntary activities such as breathing and heart rate
- **neuron (NEU rohn):** basic unit of structure and function in the nervous system; conducts impulses throughout the nervous system; composed of dendrites, a cell body, and an axon
Section 35.3 The Endocrine System

Before You Read

The endocrine system releases chemicals called hormones directly into the bloodstream. These hormones control many of the body's functions. One important hormone is the human growth hormone. What role do you think this hormone serves in helping the body function? When do you think this hormone is most important to human development? Write your response on the lines below.

Read to Learn

Control of the Body

Internal control of the body is directed by two systems. In this section you will learn about the endocrine system. Later, you will learn about the other system, the nervous system. The functions of all body systems are controlled by the interaction between the nervous system and the endocrine system. As you will recall, in mammals, a gland is a cell or a group of cells that secretes fluid. The endocrine system is made up of a series of glands, called endocrine glands. Endocrine glands release chemicals directly into the bloodstream. These chemicals relay information to other parts of the body.

How do the nervous and endocrine systems interact?

The endocrine system and the nervous system work together much of the time. The two systems maintain homeostasis in the body. As you will recall, homeostasis is the ability of a living organism to maintain internal equilibrium or conditions that enable it to survive. Because there are two control systems within the human body, the nervous system and the endocrine system, coordination is needed between the two. The hypothalamus (hi poh THA huh mus) is the part of the brain that connects the endocrine system and the nervous system. The hypothalamus receives messages from other areas of the brain. It also receives messages from the internal organs. When a change in homeostasis is detected, the hypothalamus stimulates the pituitary gland.

The pituitary gland (psh TEW oh ter e) is the main gland of the endocrine system. The pituitary gland is located in the skull, just beneath the hypothalamus. The hypothalamus controls the pituitary gland. The two are connected by nerves and by blood vessels. When the hypothalamus receives messages, the pituitary gland releases its own chemicals, or it stimulates other glands to release their chemicals. The pituitary gland controls endocrine glands, including the thyroid gland, the adrenal glands, and glands associated with reproduction.

How do hormones travel?

The endocrine glands secrete chemicals called hormones into the bloodstream. Remember that a hormone is a chemical that is released in one part of an organism that affects another part of the organism. Hormones carry information to other cells in the body. Hormones give these other cells instructions regarding metabolism, growth, development, and behavior. Once a gland releases the hormone, the hormones travel in the bloodstream. Hormones then attach themselves to target cells. Target cells have specific binding sites for hormones. These binding sites are located either on the plasma membranes, or in the nuclei of these cells. The binding sites on target cells are called receptors.

How does human growth hormone (hGH) work?

Human growth hormone, hGH, provides a good example of an endocrine system hormone. When your body is actively growing, blood glucose levels are slightly lowered because the growing cells use up the sugar. The hypothalamus detects the low blood glucose level. The hypothalamus then stimulates the production and release of hGH from the pituitary gland into the bloodstream. The hormone hGH binds to receptors on the plasma membranes of liver cells. This, in turn, stimulates...
**Negative Feedback Control**

If homeostasis is disrupted, the body responds. The endocrine glands are stimulated. Endocrine glands can be stimulated by the nervous system, by changes in blood chemistry, or by other hormones. One type of internal feedback mechanism generally controls adjustments to the endocrine system. This is called a negative feedback system. In a negative feedback system, the hormones, or their effects, are fed back to suppress or slow the original signal. Once homeostasis is reached, the signal stops. The hormone is no longer released.

**How does the feedback system work?**

Most of the endocrine glands operate under a negative feedback system. A gland synthesizes and secretes its hormone. The hormone travels in the blood to the target cells. The necessary response occurs in these target cells. Information concerning the hormone level or its effect on these target cells is fed back. The feedback is usually sent to the hypothalamus or the pituitary gland to regulate, or change, the gland’s production of the hormone.

**How do hormones controlled by the negative feedback system work?**

Antidiuretic hormone, ADH, is one of the hormones that is controlled by a negative feedback system. If you have lost water because your body has been sweating, you will feel thirsty. You feel thirsty because the water content of your body has been reduced. The hypothalamus is able to sense the concentration of water in your blood. The hypothalamus determines that your body is dehydrated. It responds by stimulating the pituitary gland to release antidiuretic (an-thi-ure-tik) hormone (ADH).

Antidiuretic hormone (ADH) reduces the amount of water in your urine. The hormone binds to receptors in the kidney cells. In the kidneys, the hormone ADH promotes the reabsorption of water. ADH also reduces the amount of water that is excreted in urine. Information about the blood water levels is constantly fed back to the hypothalamus. The hypothalamus can then regulate the pituitary gland’s release of ADH. If the body becomes overhydrated, or has too much water, the hypothalamus stops stimulating the release of ADH.
Following Digestion of a Meal, continued

Where does chemical digestion begin?

Chemical digestion begins in the mouth. Salivary glands in your mouth secrete saliva. Saliva contains a digestive enzyme called amylase. Amylase breaks down the starches in food into smaller molecules. Many of the nutrients in the food you eat contain starches, large molecules known as polysaccharides. The polysaccharides are broken down into di- or monosaccharides in the stomach, which is a muscular, pouchlike enlargement of the digestive tract. Amylase digests the swallowed starches for about 30 minutes.

What happens after you have swallowed your food?

Once food is chewed, the tongue shapes it into a ball. The tongue moves this ball of chewed food into the back of the mouth. The food is swallowed. Swallowing food forces it from the mouth into the throat. Food then moves from the mouth into the esophagus. The esophagus is a muscular tube that connects the mouth to the stomach. Food moves down the esophagus by peristalsis. Peristalsis (per uh STAHHL sus) is a series of involuntary, smooth muscle contractions along the walls of the digestive tract. The contractions occur in waves called peristaltic waves. First, circular muscles relax and longitudinal muscles contract. Then, circular muscles contract and longitudinal muscles relax. Since smooth muscles are involuntary, you do not consciously control these contractions.

When you swallow, food enters the esophagus. Usually, a flap of cartilage called the epiglottis (ep uh GLAH tuh) closes over the opening to the respiratory tract as you swallow. This prevents food from entering the respiratory tract. If you talk while swallowing, the epiglottis may open, and food can enter the respiratory tract. The body responds by choking and coughing, forcing the food out of the respiratory tube and back into the throat.

The Stomach

When chewed food reaches the end of the esophagus, it enters the stomach. The stomach is a muscular, pouchlike enlargement of the digestive tract. Both mechanical and chemical digestion take place in the stomach.

How do muscles in the stomach break down food?

The stomach contains three layers of involuntary muscles. They lie across each other, and they are located within the stomach’s walls. When these muscles contract, they physically break down swallowed food into smaller pieces. As the muscles continue to work on the pieces of food, the pieces are mixed with digestive juices produced by the stomach.

How do chemicals in the stomach break down food?

The inner lining of the stomach contains millions of glands. These glands secrete a mixture of chemicals called gastric juice. Gastric juice contains pepsin and hydrochloric acid. Pepsin is an enzyme that begins the chemical digestion of proteins in food. Pepsin works best in an acidic environment. This environment is provided by hydrochloric acid.

Food stays in the stomach for about two to four hours. When food is ready to leave the stomach, its consistency is similar to the consistency of tomato soup. Peristaltic waves become stronger and force small amounts of the liquid out of the stomach and into the small intestine.
Following Digestion of a Meal, continued

The Small Intestine

The small intestine is a muscular tube about 6 m long. It is called small because it has a narrow diameter. Its diameter is only about 2.5 cm. Food digestion is completed in the small intestine. Muscular contractions continue to help break down the food mechanically. Carbohydrates and proteins undergo additional chemical digestion. The pancreas and the liver secrete enzymes that break down the food substances even further.

What is the purpose of the duodenum?

The first 25 cm of the small intestine is called the duodenum (doo ah DEE num). Most of the enzymes and chemicals that work in the duodenum enter it through ducts that collect juices from the pancreas, the liver, and the gallbladder. Food does not pass into these organs but they all help in the digestive process.

How does the pancreas help in the digestion process?

The pancreas is a soft, flattened gland that secretes both digestive enzymes and hormones. The enzymes that the pancreas secretes break down carbohydrates, proteins, and fats. Alkaline pancreatic juices also help to neutralize the acidity of the liquid food in the small intestine. This stops any further action of pepsin.

How does the liver help in the digestion process?

The liver is a large, complex organ that has many functions. It produces bile. Bile is a chemical substance used in digestion that breaks down fats mechanically. Bile breaks large drops of fat into smaller droplets. After the liver makes bile, the bile is stored in the gallbladder. The gallbladder is a small organ located just under the liver. Bile passes from the gallbladder into the duodenum.

How is food absorbed?

After it leaves your stomach, liquid food stays in the small intestine for three to five hours. The food moves slowly through the small intestine by peristalsis. As digested food moves through the small intestine, it passes over thousand of villi. A villus (plural, villi) is a tiny, fingerlike structure. Villi are projections on the lining of the small intestine that help absorb digested food. Because villi increase the surface area of the small intestine, they allow the body to absorb more food from the small intestine.

Digested food in the small intestine is in the form of small molecules. These small molecules can be absorbed into the cells of the villi. The food molecules diffuse into the blood vessels of the villus and enter the body's bloodstream. Villi are the link between the digestive system and the circulatory system.

The Large Intestine

The material that cannot be digested in the small intestine passes into the large intestine. The large intestine is a muscular tube that is also called the colon. The large intestine, or colon, is only about 1.5 m long but is about 6.5 cm in diameter. The large intestine is much wider than the small intestine. The appendix is a tubelike extension off the large intestine. It seems to serve no purpose in human digestion.

What does bacteria in the large intestine do?

The human body does not waste water. The walls of the large intestine absorb water and salts from the indigestible material. A more solid material remains in the large intestine. Anaerobic bacteria in the large intestine produce some B vitamins and vitamin K. Both these vitamins are absorbed as needed by the body. Other bacteria in the large intestine stop harmful bacteria from colonizing. This helps to reduce the risk of infections in the intestines.

How are wastes eliminated?

After 18 to 24 hours in the large intestine, indigestible material, now called feces, reaches the rectum. The rectum is the last part of the digestive system. Feces are eliminated from the rectum through the anus.
37.3 The Excretory System

Before You Read

You may have the responsibility of taking the trash out from your home. Sometimes, just a few days of not taking out the trash can make your home or room look pretty icky. Your kidneys remove wastes from your blood. On the lines below, write what might happen if the kidneys did not remove wastes from the blood.

Read to Learn

**Kidneys: Structure and Function**

The urinary system is made up of two kidneys, a pair of ureters, the urinary bladder, and the urethra. The kidneys filter the blood to remove wastes from it. This maintains the homeostasis of body fluids. Homeostasis is the process of maintaining equilibrium. Your kidneys are located just above the waist, behind the stomach. One kidney lies on each side of the spine, partially surrounded by ribs. Each kidney is connected to a tubule called a ureter, which leads to the urinary bladder. The urinary bladder is a bag made of smooth muscle. It stores a solution of wastes. See the illustration at left.

**What is a nephron?**

Each kidney is made up of about one million tiny filters. A filter is a device that removes impurities from a solution. Each filtering unit of a kidney is called a nephron.

Blood entering a nephron carries wastes produced by body cells. The blood entering the nephron is under high pressure. It immediately flows into a bed of capillaries called the glomerulus. Because of the pressure, water, glucose, vitamins, amino acids, protein waste products (called urea), salt, and ions from the blood pass out of the capillaries into a part of the nephron called the Bowman’s capsule. Blood cells and most proteins are too large to pass through the walls of a capillary, so these components stay within the blood vessels.

The liquid forced into the Bowman’s capsule passes through a narrow, U-shaped tube. As the liquid moves along the tube, most of the ions and water and all of the glucose and amino acids are reabsorbed into the bloodstream. This reabsorption of substances is the process by which the body’s water is conserved and homeostasis is maintained.

Small molecules, including water, move back into the capillaries by diffusion. Other molecules and ions move back into the capillaries by active transport.

The liquid that remains in the tubules, composed of waste molecules, excess water, and ions, is urine. Humans produce about 2 L of urine a day. This waste fluid flows out of the kidneys, through the ureters, and into the urinary bladder where it may be stored. Urine passes from the urinary bladder out of the body through a tube called the urethra (yoo REE thruh).

The Excretory System and Homeostasis

The major waste products of cells are nitrogenous wastes, which come from the breakdown of proteins. These wastes include ammonia and urea. Both compounds are toxic to the human body and must be removed from the blood regularly. In addition to removing these wastes, the kidneys control the level of sodium in blood by removing and reabsorbing sodium ions. This helps control the osmotic pressure of the blood. The kidneys also regulate the pH of blood by filtering out hydrogen ions and allowing bicarbonate to be reabsorbed into the blood. Glucose is a sugar that is not usually filtered out of the blood by the kidneys. Individuals with diabetes have too much glucose in their blood.